

INVESTIGATION OF SPECIAL STEELS

BY

E. E. ANDREWS and R. A. WINSER

Armour Institute of Teehnology

1908

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Investigation of Special  
Steels

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A Thesis  
Presented to the President and Faculty  
of  
Armour Institute of Technology  
for  
The degree of Bachelor of Science  
in  
Chemical Engineering

Submitted by

E. E. Andrews and Roy A. Winsor.

June 1908.

Approved: *A. M. McCormack.*

*J. M. Raymond*  
Dean of Eng. Studies

*L. C. Morin*  
Dean of the Cultural Studies.

the  $\mathcal{H}_2$  norm of the error signal  $\|e\|_2$  is

$$\|e\|_2^2 = \int_0^\infty e^T e \, dt = \int_0^\infty \text{tr} \{ e^T e \} \, dt$$

$$= \int_0^\infty \text{tr} \{ e^T \dot{e} + e^T e \} \, dt$$

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An Investigation  
of  
SPECIAL STEELS

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1. *Chlorophyll a* (Chl *a*)

$\frac{d}{dt} \left( \frac{\partial L}{\partial \dot{x}} \right) = \frac{\partial L}{\partial x}$

$$P = \frac{1}{2} \left( \frac{1}{2} + \frac{1}{2} \right) = \frac{1}{2}$$

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$$\sum_{k=1}^{\infty} \frac{1}{k^2} = \frac{\pi^2}{6}$$

[illegible]

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## I. OBJECT.

The object of this thesis is to obtain several samples of special steels put on the market by the best firms in the country and to make a complete chemical, physical and mechanical analyses of each; and to thoroughly discuss each head.

## II. Method.

### (A)

#### Chemical Analysis of Special Steels.

(a) The samples of steel are usually too hard to be drilled so the sample is broken up in a steel mortar to the size of small rice grains, and thoroughly mixed before the sample is taken for analysis.

(b) Determination of Sulphur, Silicon, Tungsten, Manganese, Chromium, Phosphorus and Carbon.

Weigh 5.0 grams of the sample into a 500 cc. evolution flask, so arranged that the gases evolved on the addition of 30 cc. hot water and 30 cc. concentrated hydrochloric acid, shall be absorbed in an ammoniacal cadmium chloride solution contained in an absorption flask.

The solution is made as rapidly as possible by the addition of heat. When the steel has dissolved the solution is boiled for a minute or two so that steam may expel all the hydrogen sulphide. The sulphur is then determined by titration with iodine solution in the usual manner.

The solution in the evolution flask is transferred to a 5 in. evaporating dish. Ten cubic centimeters of concentrated nitric acid are added and the solution evaporated to dryness on the hot plate; taken up with 15 cc. concentrated HCl and again evaporated to dryness, taken up with 20 cc. concentrated HCl, diluted to about 100 cc. with distilled water, boiled and filtered. All the silica and tungsten acid will be on the filter paper, after washing thoroughly with a 5% nitric acid solution the residue is ignited in a weighed platinum crucible as

The first part of the report deals with the general situation of the country and the progress of the work done during the year. It is followed by a detailed account of the various projects and the results achieved. The report concludes with a summary of the work done and the progress made.

Summary

The summary of the work done during the year is as follows: The first part of the report deals with the general situation of the country and the progress of the work done during the year. It is followed by a detailed account of the various projects and the results achieved. The report concludes with a summary of the work done and the progress made.

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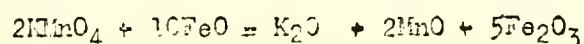
The eighth part of the report deals with the various projects and the results achieved. It is followed by a detailed account of the various projects and the results achieved. The report concludes with a summary of the work done and the progress made.

The ninth part of the report deals with the various projects and the results achieved. It is followed by a detailed account of the various projects and the results achieved. The report concludes with a summary of the work done and the progress made.

The tenth part of the report deals with the various projects and the results achieved. It is followed by a detailed account of the various projects and the results achieved. The report concludes with a summary of the work done and the progress made.

$\text{WO}_3 + \text{SiO}_2$  and weighed. A few drops of hydrofluoric acid are now added and the crucible is heated slowly until contents is dry, then to a bright red for 10 minutes to volatilize  $\text{SiO}_2$ . The loss is  $\text{SiO}_2$  and is calculated to  $\text{Si}$ ; the residue in the crucible is tungstic acid which is calculated to tungsten. This residue generally contains a trace of iron which can easily be determined by fusing the residue, after the weight has been taken, with sodium carbonate, and fitting off the oxide of iron after solution in hot water.

The filtrate from the tungstic acid and silica is placed in an evaporating dish and again evaporated to small bulk. Fifty cc. of concentrated  $\text{HNO}_3$  are added and the solution boiled until no more fumes come off, showing that all hydrochloric acid has been expelled. Enough concentrated  $\text{HNO}_3$  is now added to bring the volume up to 200 cc. and the solution again heated. When it has reached the boiling point, 10 grams of  $\text{KClO}_3$  are added and the solution evaporated down to 75 cc. in order to remove all chlorine. The manganese will now be completely precipitated as manganese dioxide and the chromium will be converted to chromic acid. The solution is filtered on asbestos, while hot and washed a few times with freshly boiled concentrated nitric acid. The manganese is then dissolved with hot  $\text{HCl}$  and a small amount of potassium nitrate. It is brought to a boil to drive off chlorine and the traces of iron are precipitated by ammonia and ammonium acetate; the basic precipitate is dissolved and reprecipitated to free it from traces of manganese. In the filtrate the manganese is precipitated by adding one gram of sodium phosphate then making the solution slightly alkaline. The solution is boiled and stirred until the precipitate assumes its characteristic appearance, then filtered, washed, ignited and weighed as  $\text{MnP}_2\text{O}_7$ . In the filtrate from the first precipitation of the manganese, the chromium is determined by titration with ferrous sulphate and potassium permanganate according to the following reactions;





If the solution is diluted to about 500 cc. and cooled to about 20 c. before titration, there is no danger of the nitric acid interfering with the titration. Each cc. of N/10  $\text{FeSO}_4$  solution used equals \_\_\_\_\_ grams of chromium.

For the determination of phosphorus 5 grams are weighed into a porcelain dish and 60 cc. of dilute nitric acid added. If more than 1% of chromium is present some HCl will also have to be used to aid in dissolving. Solution must be complete before allowing the evaporating to go too far, or it will be hard to dissolve all the steel. The residue is baked as used in phosphorus determinations, 20 cc. HCl added and the solution again taken to dryness, taken up in 20 cc. hydrochloric acid, again diluted and filtered to free from silicon and tungsten.

To the HCl solution, 35 cc. ammonia are added, then sufficient  $\text{HNO}_3$  to redissolve the ferric hydroxide. One hundred cc. of molybdate solution are added and the flask shaken for a few minutes. After standing for one hour the yellow precipitate is filtered through a weighed Gooch crucible washed with 1% nitric acid, dried for an hour at  $80^\circ$  and weighed as ammonium phosphomolybdate which contains 1.63% phosphorus.

For carbon, 1.5 grams are dissolved in 100 cc. of a 33% copper and potassium chloride solution. After standing half an hour 5 cc. hydrochloric acid are added to hasten solution. When all the precipitated copper has been redissolved, the solution is filtered through ignited asbestos in a platinum filter tube, using suction to hasten filtration. The carbon is washed a few times with hot water, then dried, ignited in a combustion tube and the evolved  $\text{CO}_2$  absorbed in weighed KOH bulbs.

1. The first step in the process of creating a new product is to identify a market need. This involves conducting market research to determine what consumers want and what problems they are trying to solve. Once a need is identified, the next step is to develop a concept that addresses that need. This is often done through brainstorming and sketching ideas. The third step is to create a prototype, which is a physical model of the product. This allows the designer to test the product and make improvements before moving forward. Finally, the product is manufactured and distributed to the market. Throughout this process, it is important to keep the target audience in mind and to iterate on the design as needed.

and the  $\mathbb{Z}_2$ -action on  $\mathbb{Z}_2$  is trivial. The  $\mathbb{Z}_2$ -action on  $\mathbb{Z}_2$  is trivial.

(b) The  $\mathcal{O}(\epsilon^2)$  term is given by

$$E_{\text{eff}} = \frac{\sum_{j=1}^n E_j}{n} = \frac{1}{n} \sum_{j=1}^n E_j$$
[illegible]

1. The first step is to identify the problem. This involves understanding the situation, gathering information, and defining the problem clearly.

[illegible][illegible]

$\mathbf{A} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

1. The first step is to identify the problem or question that needs to be answered. This involves understanding the context and the specific requirements of the task.

[illegible]

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[illegible]

ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED

1. The first step is to identify the problem or question that needs to be answered. This involves understanding the context and the specific requirements of the task.

*Journal of Management Studies*, 19(1), 67-80.

### (8) Determination of Nickel.

Two grams of the sample are dissolved in 55 cc. concentrated HCl and 1 cc. HNO<sub>3</sub> and evaporated to 10 cc. Transfer to a 250 cc. separating funnel and use as little warm hydrochloric acid (2:1) as possible in rinsing the material into the funnel. Cool and add 40 cc. of pure ether which has been previously agitated with 5 cc. of HCl. Shake vigorously, cooling from time to time. Allow to stand and run off the aqueous solution. Wash the ether by shaking with two portions of 5 cc. each of hydrochloric acid (sp.gr. 1.13) Boil out the ether, precipitate the iron with ammonia, adding a little bromine water to precipitate the manganese. Evaporate the excess of ammonia obtaining about 100 cc. of solution containing 1 cc. ammonia. Precipitate the nickel by hydrogensulphide, filter, wash with hydrogen sulphide water, and weigh as Ni<sub>2</sub>S containing 0.7855 nickel.

### An(9) Vanadium.

Vanadium is occasionally found in pig iron, and may be determined with great accuracy by the following method. Tread 5 grammes of the drillings with 50 cc. nitric acid (1.2 sp.gr.) in a No. 4 beaker. When all action has ceased, transfer the liquid to a porcelain dish, evaporate to dryness, and heat at a gradually increasing temperature over a Bunsen burner until the nitrates are nearly all decomposed and the mass separates easily from the bottom and sides of the dish. Transfer the cooled mass to a porcelain or agate mortar, and grind it thoroughly with 30 grammes of dry sodium carbonate and 5 grammes of sodium nitrate. Transfer to a large platinum crucible, and fuse well for about an hour at a high temperature. Run the fused mass well up on the sides of the crucible, allow it to cool, dissolve in hot water, and filter. Dilute the filtrate to about 600 cc., and add nitric acid carefully to get rid of the carbonic acid. Boil off the latter, but be careful to keep the solution always slightly alkaline. Filter, and to the filtrate add a few drops of nitric acid to make it

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faintly acid, when the appearance of a yellowish coloration is an indication of the presence of vanadic acid. Add to the solution a few cc. of mercurous nitrate, and then an excess of mercuric oxide in water, to render the solution neutral and insure the complete precipitation of all the mercurous vanadate. With the mercurous vanadate are precipitated also all the phosphoric, chromic, tungstic, and molybdate acids as mercurous salts. Heat to boiling, filter and wash the precipitate. Dry it, separate the paper, burn it in a platinum crucible, add the precipitate, heat carefully to expel the mercury, and finally heat to full redness. Fuse the brownish-red mass remaining in the crucible with a little sodium carbonate and a pinch of sodium nitrate, dissolve the cooled mass in water, and filter into a small beaker. Add to the solution pure ammonium chloride in excess (about 3.5 grammes to each 10 cc. of solution), and allow it to stand for sometime, stirring occasionally. Ammonium vanadate, insoluble in a saturated solution of ammonium chloride, separates out as a white powder. It is necessary to keep the solution decidedly alkaline, and a drop or two of ammonium must be added from time to time. The appearance of the faintest yellowish tint to the solution is evidence that it has become slightly acid, and this must be corrected or the result will be too low. Filter on a small ashless filter, wash first with a saturated solution of ammonium chloride containing a drop or two of ammonia, and then with alcohol. Dry, ignite, moisten with a drop or two of nitric acid, ignite, and weigh as vanadic acid, which contains 56.22 percent of vanadium.

#### (10) Determination of Molybdenum.

In irons and steels containing from 1 to 10 percent of molybdenum treat 1 gramme of the drillings in a beaker with from 50 cc. to 100 cc. nitric acid (1.2 sp.gr.) and heat on hot plate until all action has ceased, evaporate to dryness in an air-bath, take up with hydrochloric acid and heat until all ferric,



oxide is dissolved evaporate to dryness, take up with dilute hydrochloric acid and filter from silica; treat this residue with sulphuric and hydrofluoric acids weighing if silicon is to be determined, and after weighing the second time fuse the residue with sodium carbonate and a little sodium nitrate, dissolve in water, filter, and add filtrate to the main solution. Reduce the ferric chloride with ammonium bisulphite as in the determination of phosphorus and after having driven off the sulphurous acid, pass hydrogen sulphide gas into the solution for an hour keeping it at about  $80^{\circ}\text{C}$ . At the end of this time, make the solution chromic-acid, then acidulate with hydrochloric acid and pass hydrogen sulphide again for a few minutes; stand the beaker aside and allow the precipitate to settle until the supernatant liquid is clear, filter on paper, and wash with hydrogen sulphide water. Treat the filtrate again in the same way, and if any precipitate forms, filter on another paper. Wash the precipitates from the papers into a beaker with hot ammonium sulphide solution, burn the papers in a porcelain crucible, cover the residue in the crucible with flowers of sulphur and heat gently until the sulphur is melted, then add a little sodium carbonate, cover the crucible with a lid and heat until liquid; cool, dissolve in hot water, filter, and add the filtrate to the main solution. Warm the sulphide solution for an hour or so and filter, washing with ammonium sulphide water from any sulphides that may be insoluble in the ammonium sulphide, but which should be soluble in hydrochloric acid, unless some copper has dissolved in the previous treatment; otherwise the treatment with ammonium sulphide has been insufficient.

Heat the filtrate, which should be yellow in color, almost to boiling, and acidulate carefully with hydrochloric acid; when the acid is in excess, all the molybdenum sulphide will be precipitated, but hydrogen sulphide may be passed for a short time if necessary. Heat the solution gently until all smell of hydrogen sulphide is driven off, and filter on a weighed Gooch crucible, washing



# CHEMICAL ANALYSIS OF STEELS.

| Steel.<br>Element | Sulphur<br>per cent. | Silicon.<br>per cent. | Tungsten.<br>per cent. | Manganese<br>per cent. | Chromium.<br>per cent. | Nickle.<br>per cent. | Phosphorous<br>per cent. | Carbon.<br>per cent. |
|-------------------|----------------------|-----------------------|------------------------|------------------------|------------------------|----------------------|--------------------------|----------------------|
| Vulcan.           | .016                 | .216                  | 19.10                  | .023                   | .000                   | .526                 | .007                     | 1.074                |
| Poldi.            | .012                 | .319                  | 12.94                  | .068                   | 3.695                  | .987                 | .016                     | 1.030                |
| Heller.           | .015                 | .237                  | 8.40                   | .117                   | 5.720                  | 1.673                | .049                     | 1.010                |
| Bethlehem.        | .011                 | .192                  | 21.20                  | .144                   | 13.180                 | .055                 | .031                     | 1.020                |
| International.    | .014                 | .132                  | 11.74                  | 4.630                  | 3.170                  | .237                 | .052                     | 1.079                |

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with hot water. Dry at 100° or 120° C. and ignite in a stream of hydrogen, until weight is constant, by placing the bowl of a clay tobacco-pipe in the crucible and passing the hydrogen into the stem. The hydrogen gas must have replaced the air in the pipe and crucible before the heat is applied. Heat to dull redness for one hour, remove the heat, and allow to cool with the hydrogen passing. Weigh, and repeat the ignition; the second weight will rarely differ much from the first. The precipitate is molybdenum disulphide, which contains 60 percent of molybdenum.

## II B. (a) PHYSICAL TESTS.

An attempt was made to determine some of the physical properties of the steels. One of the most noticeable properties in a qualitative way was the slow rate of corrosion of the sample by HCl, HNO<sub>3</sub> and aqua regia. The most important physical characteristic being the tensile strength. We endeavored to obtain ~~XXXXXXXXXX~~ this quality with the testing machine of the Mechanical Laboratory. Two methods, that of pulling and of bending the test bar were used.

For the first method the Olsen tension machine was employed, test being carried out as follows:-

Test piece, square in section, was fitted into the jaws of the machine which was then operated until the wedges clamped the piece. A slow speed was then used in separating the moving heads carrying the jaws, the scale at the same time being kept balanced until the piece broke when the breaking stress was read directly from scale beam. This stress divided by original area of piece gives tensile strength at fracture. The reduction of area is determined by measuring the reduced area at the point of fracture and elongation by measuring the increment of length of the bar between two marks originally 8" apart on opposite sides of the point of fracture.

*Journal of Management Studies*, 19(6), 701-718.

1. The first step in the process of the investigation is the identification of the problem. This is done by the investigator, who is usually a member of the research team. The investigator must first identify the problem, then determine the scope of the problem, and then determine the objectives of the investigation.

2. The second step in the process of the investigation is the design of the study. This is done by the investigator, who is usually a member of the research team. The investigator must first identify the problem, then determine the scope of the problem, and then determine the objectives of the investigation.

3. The third step in the process of the investigation is the collection of data. This is done by the investigator, who is usually a member of the research team. The investigator must first identify the problem, then determine the scope of the problem, and then determine the objectives of the investigation.

4. The fourth step in the process of the investigation is the analysis of the data. This is done by the investigator, who is usually a member of the research team. The investigator must first identify the problem, then determine the scope of the problem, and then determine the objectives of the investigation.

5. The fifth step in the process of the investigation is the interpretation of the results. This is done by the investigator, who is usually a member of the research team. The investigator must first identify the problem, then determine the scope of the problem, and then determine the objectives of the investigation.

6. The sixth step in the process of the investigation is the reporting of the results. This is done by the investigator, who is usually a member of the research team. The investigator must first identify the problem, then determine the scope of the problem, and then determine the objectives of the investigation.

7. The seventh step in the process of the investigation is the evaluation of the results. This is done by the investigator, who is usually a member of the research team. The investigator must first identify the problem, then determine the scope of the problem, and then determine the objectives of the investigation.

8. The eighth step in the process of the investigation is the conclusion. This is done by the investigator, who is usually a member of the research team. The investigator must first identify the problem, then determine the scope of the problem, and then determine the objectives of the investigation.

9. The ninth step in the process of the investigation is the final report. This is done by the investigator, who is usually a member of the research team. The investigator must first identify the problem, then determine the scope of the problem, and then determine the objectives of the investigation.

10. The tenth step in the process of the investigation is the final evaluation. This is done by the investigator, who is usually a member of the research team. The investigator must first identify the problem, then determine the scope of the problem, and then determine the objectives of the investigation.

I have been thinking of you a great deal lately, and  
 wondering how you are getting on. I hope you are  
 well and happy. I have been very busy lately, but  
 I have managed to find some time to write to you.  
 I have been thinking of you a great deal lately, and  
 wondering how you are getting on. I hope you are  
 well and happy. I have been very busy lately, but  
 I have managed to find some time to write to you.

The same machine was used for the tension test by bending but a different method employed. Two knife edges were laid on the bottom plate of the machine 8" apart and the test piece laid across. A knife edge fastened to the moving plate, was brought down to touch the piece in the centre, direction of edge being parallel to that of the other two and perpendicular to axis of piece. The machine was now run at slow speed deflecting the piece until fracture occurred. According to the theory of moments fracture will occur in a specimen under these conditions when the tension in the outer fibre under the load equals the breaking load. Then if  $P$  be the load,  $l$  the length of beam,  $I$  its moment of inertia,  $e$  the distance from centre to outer fibre the equation holds

$$T \frac{I}{e} = \frac{1}{4} Pl. \text{ where } T \text{ is the ultimate tensile strength in } \frac{\text{lb}}{\text{sq in}} \text{ Hence } T = \frac{1}{4} Pl \frac{e}{I}$$

## II C. MECHANICAL TESTS.

The method adopted for mechanical test was a practical shop test consisting of making tools of the steels, tempering them according to makers instructions and running cuts with the tools on cast iron and steel pieces in a lathe under standard conditions to determine life of each tool under cut. It was necessary of course in order to interpret the results that the shape, cutting angles and heat treatment of each tool should be identical and that the feed, depth of cut and cutting speed should also be the same or if not so that some method be available of reducing these elements if variable to expression in terms of standard conditions. As our test pieces were not large enough to allow us to satisfy these last conditions we were forced to use formulae given by Mr. Taylor of the American Mechanical Society on the effect of the variable, cutting speed, in order to compare our results.

The tools were forged into small tools of the shape and dimensions given

*[The page contains faint, illegible mirrored text from the reverse side.]*

1950-1951

1. The first of these is the fact that the Government has not been able to secure the necessary funds to carry out its policy of non-interference in the internal affairs of other countries. This is due to the fact that the Government has not been able to secure the necessary funds to carry out its policy of non-interference in the internal affairs of other countries.

# Results of Physical Test.

| Steel  | Tensile Strips         | Elong. % | Reduction in Area. |
|--------|------------------------|----------|--------------------|
| Vulcan | 116,300 $\frac{F}{12}$ | 6.5%     | 24.8%              |
| Heller | 123,800 $\frac{F}{12}$ | 6.1%     | 11.6%              |

## Results of Mechanical (Shop) Tests.

### A - Cutting Hard Cast Iron.

| Steel Used | Feed $\frac{1}{16}$ rev | Depth Cut $\frac{1}{16}$ | Cut. Speed $\frac{1}{16}$ min. | Life min. | Life-calc to 51' speed | Life-calc to $\frac{1}{16}$ feed $\frac{1}{16}$ cut 51' min. |
|------------|-------------------------|--------------------------|--------------------------------|-----------|------------------------|--|
| Poldi      | $\frac{1}{36}$          | $\frac{1}{16}$           | 51                             | 11.5      | 11.5                   | 11.5   |
| Inter.     | "                       | "                        | 54                             | 15.7      | 24.8                   | 24.8   |
| Heller     | "                       | "                        | 51                             | 12.7      | 12.7                   | 12.7   |
| Bethl.     | "                       | "                        | 51                             | 3.5       | 3.5                    | 3.5  |
| Vulcan     | "                       | "                        | 54                             | 3.1       | 4.9                    | 4.9  |
| Poldi      | $\frac{1}{18}$          | $\frac{1}{32}$           | 51                             | 13.0      | 13.0                   | 36.4   |
| Inter      | "                       | "                        | 51                             | 8.2       | 8.2                    | 23.0   |
| Heller     | "                       | "                        | 47                             | 7.8       | 4.1                    | 22.2   |
| Bethl.     | "                       | "                        | 51                             | 7.0       | 7.0                    | 14.6   |
| Vulcan     | "                       | "                        | 47                             | 6.1       | 3.2                    | 17.3   |

### B - Cutting Steel.

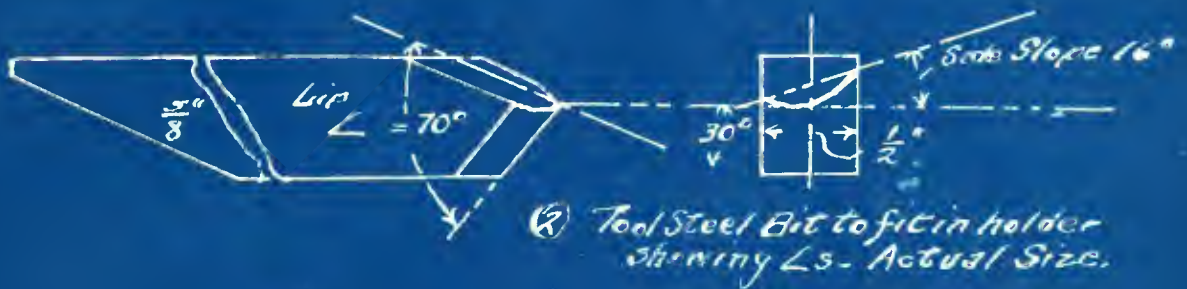
| Steel  | Feed $\frac{1}{16}$ rev | Depth $\frac{1}{16}$ | Speed $\frac{1}{16}$ min. | Life min. |
|--------|-------------------------|----------------------|---------------------------|-----------|
| Poldi  | $\frac{1}{18}$          | $\frac{1}{16}$       | 160                       | 1.00      |
| Int.   | "                       | "                    | "                         | .30       |
| Heller | "                       | "                    | "                         | .50       |
| Beth.  | "                       | "                    | "                         | .25       |
| Vulcan | "                       | "                    | "                         | .25       |

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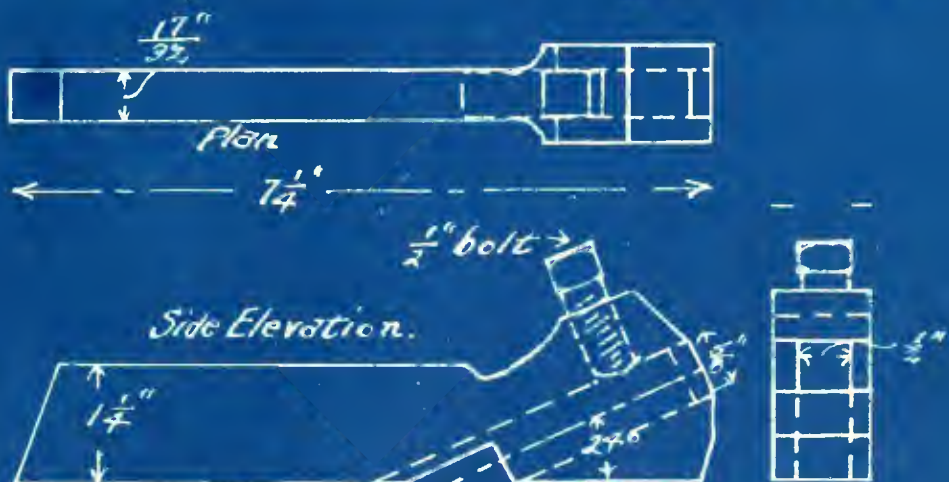
### Details of Tools & Cutting $\angle$ s.



① Diagram Showing  $\angle$ s of Cutting.



(2) Tool Steel Bit to fit in holder showing  $\angle$ s. Actual Size.



③ Diagram of Tool Holder used in Test  
Scale - 6" = 1"  
Made of Tool Steel.

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in fig. 2 and when in use were fitted into a tool holder made of tool steel in the shape and dimensions of fig. 3. The angles when the tool was cutting were then as follows: ref. fig. 1.

Angle above horizontal thru center of tool piece at which tool point touches work  $10^{\circ}$  (about)

Angle between horizontal and portion of tool in holder  $24^{\circ}$

Angle of clearance flank with tool axis  $40^{\circ}$

Angle of top of cutting edge with tool axis  $30^{\circ}$

Clearance angle between clearance flank and work  $16^{\circ}$  - Back slope  $40^{\circ}$

Side slope  $16^{\circ}$

The lip angle was  $70^{\circ}$  which is about right for C. I and slightly too blunt for medium steel.

The heat treatment was that known as self hardening and consisted in heating the tools to a bright yellow ( $1790^{\circ}$  F.) and cooling them in oil or air, fish oil being used in our case. Each tool was then ground to the above angle in a Gisholt Automatic Grinder which left the tool in the form of a "diamond nose" with a top angle of  $74^{\circ}$ ; the tip of the nose was then rounded with  $1/16"$  radius giving a round nose of the desired form. In grinding we at first used water cooling but it seemed to make the tools brittle on the edge and irregular in their working, probably due to the hardening effect of sudden cooling as when the steel became momentarily heated and suddenly cooled. In our later tests then the grinding was done dry and just before finishing each tool was held quiet against the wheel long enough to heat its edges to bright yellow when it was removed and allowed to "air harden" by cooling in the air.

The test pieces were a  $3\frac{1}{2}"$  diam. cast iron cylinder 28" in length and a  $2\frac{1}{2}"$  steel shaft 16" in length. The analysis of the cylinder was:-



|                  |      |
|------------------|------|
| Combined carbon  | .54  |
| Graphitic carbon | 3.17 |
| Silicon          | 2.02 |
| Sulphur          | .07  |
| Phosphorus       | .45  |

The metal was treated in the ladle before casting with ferromanganese which explains the low S but as the charge was chiefly old iron etc., the casting was nevertheless a very hard one. We started a roughing cut on the scale but it was so uneven that no satisfactory results could be obtained so turned this off before continuing our tests.

As the piece was not a large one it was necessary to adopt a feed, cut and speed such that the tools would wear out rapidly in order that all our tests could be made on work of the same diameter and at the same cutting speed. On the preliminary test with cut of  $1/8"$  feed  $1/36"$  and speed  $54'/\text{min}$  (gauged with a <sup>Warner</sup> cutmeter) the tool lasted 40 sec. only on C.I. so we changed the cut to  $1/16"$  with  $1/36"$  ~~with~~ feed and  $54'/\text{min}$ . and later to  $1/32"$  with  $1/18"$  feed and  $54'/\text{min}$ . for C.I. and  $1/16"$  cut with  $1/18"$  feed and  $160'/\text{min}$ . for steel which gave a life of about 2 - 15 min. on C.I. and 10 - 60 sec. on steel.

The tools were run under these conditions in a Marshall and Huschart 18" Pat. Head Lathe driven by a Northern Variable speed. 4 pole, 110 v. 20 amp. 2.5 H.P. motor running at 500 - 1000 r.p.m. In order to measure the power used a 0-50 Weston ammeter was connected in series with the armature and a 0 - 150 Weston voltmeter in parallel the power output in watts being:- if R = armature resistance.  $P = EI - RI^2 = EI (1-.52I)$  R being obtained by passing a current when the armature was stationary as

2 volts  $\div$  3.85 amperes = .52 ohms. The quantities noted were

(a) Power Input at different portions of cut

(b) Feed, Cut, constant

1  
4 5 6 7

1864

10

1

2 3 4 5  
 4 5 6 7

• • •

1. *U. pinnatifida* (L.) (Fig. 1)

1. The first step is to identify the problem or question that needs to be answered. This involves understanding the context and the specific requirements of the task.

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1. The first step is to identify the problem or question that needs to be answered. This involves understanding the context and the specific requirements of the task.

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*Journal of Management Inquiry* 18(6)br/>DOI: 10.1177/1056492609356111  
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1990 年 12 月 20 日

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*Journal of Management Studies*, 20(6), 791-806.

10. The following is a list of the names of the persons who have been appointed to the various committees of the Board of Directors of the Corporation:

... ..

[illegible][illegible]

1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2084, 2085, 2086, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2100, 2101, 2102, 2103, 2104, 2105, 2106, 2107, 2108, 2109, 2110, 2111, 2112, 2113, 2114, 2115, 2116, 2117, 2118, 2119, 2120, 2121, 2122, 2123, 2124, 2125, 2126, 2127, 2128, 2129, 2130, 2131, 2132, 2133, 2134, 2135, 2136, 2137, 2138, 2139, 2140, 2141, 2142, 2143, 2144, 2145, 2146, 2147, 2148, 2149, 2150, 2151, 2152, 2153, 2154, 2155, 2156, 2157, 2158, 2159, 2160, 2161, 2162, 2163, 2164, 2165, 2166, 2167, 2168, 2169, 2170, 2171, 2172, 2173, 2174, 2175, 2176, 2177, 2178, 2179, 2180, 2181, 2182, 2183, 2184, 2185, 2186, 2187, 2188, 2189, 2190, 2191, 2192, 2193, 2194, 2195, 2196, 2197, 2198, 2199, 2200, 2201, 2202, 2203, 2204, 2205, 2206, 2207, 2208, 2209, 2210, 2211, 2212, 2213, 2214, 2215, 2216, 2217, 2218, 2219, 2220, 2221, 2222, 2223, 2224, 2225, 2226, 2227, 2228, 2229, 2230, 2231, 2232, 2233, 2234, 2235, 2236, 2237, 2238, 2239, 2240, 2241, 2242, 2243, 2244, 2245, 2246, 2247, 2248, 2249, 2250, 2251, 2252, 2253, 2254, 2255, 2256, 2257, 2258, 2259, 2260, 2261, 2262, 2263, 2264, 2265, 2266, 2267, 2268, 2269, 2270, 2271, 2272, 2273, 2274, 2275, 2276, 2277, 2278, 2279, 2280, 2281, 2282, 2283, 2284, 2285, 2286, 2287, 2288, 2289, 2290, 2291, 2292, 2293, 2294, 2295, 2296, 2297, 2298, 2299, 2300, 2301, 2302, 2303, 2304, 2305, 2306, 2307, 2308, 2309, 2310, 2311, 2312, 2313, 2314, 2315, 2316, 2317, 2318, 2319, 2320, 2321, 2322, 2323, 2324, 2325, 2326, 2327, 2328, 2329, 2330, 2331, 2332, 2333, 2334, 2335, 2336, 2337, 2338, 2339, 2340, 2341, 2342, 2343, 2344, 2345, 2346, 2347, 2348, 2349, 2350, 2351, 2352, 2353, 2354, 2355, 2356, 2357, 2358, 2359, 2360, 2361, 2362, 2363, 2364, 2365, 2366, 2367, 2368, 2369, 2370, 2371, 2372, 2373, 2374, 2375, 2376, 2377, 2378, 2379, 2380, 2381, 2382, 2383, 2384, 2385, 2386, 2387, 2388, 2389, 2390, 2391, 2392, 2393, 2394, 2395, 2396, 2397, 2398, 2399, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2408, 2409, 2410, 2411, 2412, 2413, 2414, 2415, 2416, 2417, 2418, 2419, 2420, 2421, 2422, 2423, 2424, 2425, 2426, 2427, 2428, 2429, 2430, 2431, 2432, 2433, 2434, 2435, 2436, 2437, 2438, 2439, 2440, 2441, 2442, 2443, 2444, 2445, 2446, 2447, 2448, 2449, 2450, 2451, 2452, 2453, 2454, 2455, 2456, 2457, 2458, 2459, 2460, 2461, 2462, 2463, 2464, 2465, 2466, 2467, 2468, 2469, 2470, 2471, 2472, 2473, 2474, 2475, 2476, 2477, 2478, 2479, 2480, 2481, 2482, 2483, 2484, 2485, 2486, 2487, 2488, 2489, 2490, 2491, 2492, 2493, 2494, 2495, 2496, 2497, 2498, 2499, 2500, 2501, 2502, 2503, 2504, 2505, 2506, 2507, 2508, 2509, 2510, 2511, 2512, 2513, 2514, 2515, 2516, 2517, 2518, 2519, 2520, 2521, 2522, 2523, 2524, 2525, 2526, 2527, 2528, 2529, 2530, 2531, 2532, 2533, 2534, 2535, 2536, 2537, 2538, 2539, 2540, 2541, 2542, 2543, 2544, 2545, 2546, 2547, 2548, 2549, 2550, 2551, 2552, 2553, 2554, 2555, 2556, 2557, 2558, 2559, 2560, 2561, 2562, 2563, 2564, 2565, 2566, 2567, 2568, 2569, 2570, 2571, 2572, 2573, 2574, 2575, 2576, 2577, 2578, 2579, 2580, 2581, 2582, 2583, 2584, 2585, 2586, 2587, 2588, 2589, 2590, 2591, 2592, 2593, 2594, 2595, 2596, 2597, 2598, 2599, 2600, 2601, 2602, 2603, 2604, 2605, 2606, 2607, 2608, 2609, 2610, 2611, 2612, 2613, 2614, 2615, 2616, 2617, 2618, 2619, 2620, 2621, 2622, 2623, 2624, 2625, 2626, 2627, 2628, 2629, 2630, 2631, 2632, 2633, 2634, 2635, 2636, 2637, 2638, 2639, 2640, 2641, 2642, 2643, 2644, 2645, 2646, 2647, 2648, 2649, 2650, 2651, 2652, 2653, 2654, 2655, 2656, 2657, 2658, 2659, 2660, 2661, 2662, 2663, 2664, 2665, 2666, 2667, 2668, 2669, 2670, 2671, 2672, 2673, 26

the 1990s, the number of people in the world who are undernourished has declined from 1.1 billion to 800 million. The number of people who are malnourished has declined from 1.5 billion to 1 billion. The number of people who are obese has increased from 100 million to 300 million. The number of people who are overweight has increased from 100 million to 300 million. The number of people who are obese and overweight has increased from 100 million to 300 million. The number of people who are obese and overweight has increased from 100 million to 300 million.

6. *Journal of the American Medical Association*, 1990; 263: 1025-1028.

*Journal of Management Education* 30(6)p.789-804

\* 1990年12月25日，在《人民日报》发表署名文章《中国要警惕“新左派”的泛滥》。

*Journal of Management Studies*, 1986, 23(1), 7-10.

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(c) Diameter of work and cutting speed.

(d) Condition of tool to determine life.

The tools, unless they broke immediately on touching the work, generally ~~ran~~ pretty well with low power input to the lathe for some time. Then as the edge became dulled the power input gradually increased, work becoming slightly rougher until suddenly the edge of the tool would soften, power input increases very much and the work and tool push slightly apart the diameter of the work increased. This phenomena generally took about 4 - 10 seconds and on stopping the work the tool would be found to have lost its edge completely the appearance being as if it were fused at the cutting point by the friction. This point of complete ruination of the tool was judged the end of its life.

### III. B. PHYSICAL TESTS.

The data obtained in the physical tests was very meagre. In the test of tensile strength by direct pulling the test jaws of the machine were broken on our third specimen and we gave up this method of attack as too expensive and tried instead the method of breaking the piece by flexure. The first piece tested in this way scattered all over the laboratory on fracture and gave an indicated tensile strength of  $229,000 \frac{\text{lb}}{\text{in}^2}/\text{T}$  which showed that this method did not give reliable results. Hence we did not make any more tests by this method. The data obtained on the first two specimens is given on p. No. further data was obtained.

### III. C. MECHANICAL TESTS.

The data observed, as noted in II C, were feed, depth of cut, speed, power input to lathe, and life as measured from start of cut to running point of tool. In cutting the C I piece we could not get all our cuts on one diameter of work with the result that two cutting speeds were obtained  $54 \text{ '}/\text{min.}$  and  $51 \text{ '}/\text{min.}$  and the only way to reduce the cuts to standard was to correct one ( $51 \text{ '}/\text{min.}$ ) to life when cutting at  $54 \text{ '}/\text{min.}$  by a formula of Mr. Taylor

[illegible]

$$\frac{T_1}{T_2} = \left( \frac{V_2}{V_1} \right)^8 \quad T_1 \text{ and } T_2 \text{ being life and } V_1 \text{ and } V_2 \text{ being cutting speeds. In}$$

several cases the tools broke almost immediately on touching the rapidly running work and the results in these cases were not considered worth keeping. In another case a tool gave much shorter life when the iron was interrupted and then started again than when on a continuous run, but this run was not thought worth keeping as being exceptional. The dimensions of the test pieces were not such as would allow more than one test of each piece and the only duplicate runs obtained were those on C.I. at the two different conditions. For purposes of comparison the run on C.I. at  $1/36''$  cut x  $1/18''$  feed and 51 ft. speed is reduced to 54' speed,  $1/16''$  cut and  $1/36''$  feed by Taylor's formula for  $1/2''$  round nose tool

$$\frac{V_1}{V_2} = \frac{F_2^{.665} \left( \frac{48}{3} D_2 \right)^{.2273 + \frac{2.4}{18+48D}}}{F_1^{.665} \left( \frac{48}{3} D_1 \right)^{.2273 + \frac{2.4}{18+48D}}}$$

giving the velocity for same life at feed twice the cut and  $1/2$  the feed and then figuring the life at  $V' = 54'$  by  $T_1 = \left( \frac{V_1}{V'} \right)^8$  The data obtained and figured

in this way is given on table P. and further consideration of it is reserved for part IV. As the power varied so much and so erratically that accurate readings were not possible the input is not tabulated, it being noted however that the power input into the lathe was increased from 15 - 25% when the tool gave out.

#### IV A. (a) DISCUSSION AND CONCLUSIONS - CHEMICAL.

The chemical constitution is of the greatest importance in all steels since this factor together with the heat treatment is what makes one steel different from another. The most important constituents of ordinary carbon tool steel

$\frac{1}{\sqrt{\pi}} \int_{-\infty}^{\infty} f(x) e^{-x^2} dx = \frac{1}{\sqrt{\pi}} \int_{-\infty}^{\infty} f(x) e^{-x^2} dx$

$$J^{\alpha} \left( \frac{1}{\Gamma(\alpha)} \int_0^t (t-s)^{\alpha-1} f(s) ds \right) = \frac{1}{\Gamma(\alpha)} \int_0^t (t-s)^{\alpha-1} J^{\alpha} f(s) ds, \quad \alpha \in (0, 1), \quad t \in [0, T].$$

Figure 1. The effect of the concentration of the  $\text{H}_2\text{O}_2$  solution on the amount of the  $\text{Fe}^{2+}$  ions in the solution. The concentration of the  $\text{Fe}^{2+}$  ions in the solution was 0.01 M, and the concentration of the  $\text{H}_2\text{O}_2$  solution was 0.01 M. The concentration of the  $\text{H}_2\text{O}_2$  solution was 0.01 M. The concentration of the  $\text{H}_2\text{O}_2$  solution was 0.01 M.

[illegible]

Figure 1. The effect of the initial concentration of the monomer on the polymerization of  $\alpha$ -methylstyrene initiated by  $\text{TiCl}_4$  in  $\text{CH}_2\text{Cl}_2$  at  $-78^\circ\text{C}$ . The concentration of the initiator was  $1.0 \times 10^{-2}$  mole/l. The concentration of the monomer was 0.05 mole/l. (O)  $\text{TiCl}_4$  alone; (●)  $\text{TiCl}_4$  with  $\text{Ti}(\text{O}i\text{Pr})_3$  (1.0 mole-%); (▲)  $\text{TiCl}_4$  with  $\text{Ti}(\text{O}i\text{Pr})_3$  (2.0 mole-%); (□)  $\text{TiCl}_4$  with  $\text{Ti}(\text{O}i\text{Pr})_3$  (5.0 mole-%).

Figure 1. The effect of the concentration of the *Agrobacterium* suspension on the transformation efficiency of *Agrobacterium* strains.

are silicon, carbon, manganese, phosphorous and sulphur. In special steels there appear other elements such as Cr, Ni, W, Mo, Al, V, Ti, H, N & O.

Si is present usually in small quantities except in special silicon steels and when present up to 1.4% decreases the solubility of C. Up to 2% it increases the ductility and slightly lowers the melting point and increases the fluidity of the molten steel. Mn in small quantities (1-2%) lowers the melting point and increases the fluidity having also the property of combining with and eliminating S as Mn S. P causes steel to be brittle and easily broken by shock as does also S both of which elements should be as low as possible in a good steel.

Carbon is the most important element in steel because it gives the maximum amount of tensile strength and hardness with least decrease in ductility each.01% increasing tensile strength 800 - 1000% up to about 1% C. Phosphorous has an equal effect up to about .12% but the steel is much more brittle when hardened with P.

The hardness of steel also depends to some extent on the physical constitution of the iron. When molten steel containing 0 - 2% C solidifies the C appears to be present first as a solid solution of iron carbide in pure iron of a crystalline form known as "gamma" iron. In this form the steel is known as austenite. As the steel cools the iron changes to a second, "beta" condition, the steel passing thru the forms known as martensite and troostite and finally changes to the ordinary magnetic variety or "alpha" iron. When in this condition and before the iron carbide has separated from solid solution the substance is known as osmondite. If osmondite contains more than .9% C the carbide now separates from solution in flat scaly crystals known as cementite containing 6.6% C. and if less than .9% is present pure "alpha" iron or ferrite separates until in either case residual part containing .9% C is left. The .9% alloy consisting of 12% cementite and 88% ferrite now precipitates out in the crystalline form known as pearlite. The substance during the ~~xxxxxxxxxxxx~~ transition stage



is called sorbite and the final cool steel will be either ferrite or cementite mixed with pearlite. The change from osmondite to pearlite occurs at  $900 - 690^{\circ}$  in steel with less than .9% C and at  $690^{\circ} - 1140^{\circ}$  in steel containing .9 - 2.2% C. The other changes take place between these temperatures and the melting point of the steel.

Gamma and beta Fe are non magnetic and are harder than alpha iron. In iron, free from all impurities the change from one variety to another takes place almost instantaneously at the critical temperature during cooling but the presence of certain constituents seems to retard this action. The hardening of ordinary carbon tools is based on the retarding effect of carbon on the change in Fe to the alpha variety. If the steel be suddenly cooled when at a temperature above its critical point for pearlite formation a large part of the steel is left as martensite which is the hardest variety, scratching even austenite. Ordinary carbon steel, however, is left too brittle by this process and hence must be partially reduced to pearlite in order to make it tough. This is accomplished by heating the steel to  $200 - 300^{\circ}$  C, when a very gradual change occurs yielding pearlite to some extent and rendering the steel tough. Some other elements, notably tungsten or molybdenum together with manganese or chromium so delay the change that quenching is not necessary and the steel is called "self or air hardening", being when cold a mixture of martensite and austenite which is tougher than ordinary carbon steel. The Taylor White heat treatment of cooling the steel slowly from a white heat in certain special steels leaves the steel in the very tough austenite condition and the alloys present prevent the change to pearlite until the steel has been subsequently heated to  $650^{\circ}$  C.

Practically all the alloy steels depend largely upon this action of the metals upon the critical temperatures of iron for their properties. Hence they usually contain a small amount (.6 - 1%) of C to give the hardness and a rather high % of the alloy metal. Cr (2 - 4%) lowers the critical temperature for

[illegible]

pearlite below ordinary temperatures and yields a very hard tough steel used for projectiles, etc. Ni also lowers the critical temperature which with 25% is below ordinary temperatures so that the iron is in the beta condition and non magnetic. Ni steel has a high elastic limit and great resilience, being used for tension members on bridge work, etc. Mn also lowers the critical temperature but when present from 1 - 5.5% makes the steel very brittle. Above this point it yields a steel which on being quenched from 1000° C is mostly austenitic and is very hard and difficult to machine but so tough that it is used for very heavy duty such as rails for curves, crusher jaws, etc. Certain steels low in C and with 1 - 5% Si have higher magnetic permeability and electrical resistance than pure iron and are very useful in transformer construction.

Some metals are added to counteract the effect or eliminate absorbed gases such as H, N, O & CO which cause the steel to have blow holes or to be coarse grained by reason of FeO. Si and Mn in small quantities remove O<sub>2</sub> to some extent and assist in giving a quiet pour. Al is now much used to remove O<sub>2</sub> and give a "dead" melt. V has probably the same action as Al but cleanses so thoroughly that the tensile strength of V steels is nearly double that of ordinary steel altho the actual % V be almost zero. The life under bending strains is also much greater in V steel. Ti has been proposed to remove N but not much is known as yet of its action. Most of the alloy tool steels, however, utilize more than one metal and the resultant properties are extremely various. Thus the use of special alloys for tool steels commenced only a few years ago with the Mushet "self hardening" tools which are an alloy of 4 - 12% W, 2 - 4% Mn and 1.5 - 2.5% C with Fe. This alloy steel may be allowed to cool in the air from the heat necessary for tempering without becoming soft since the change occurs too slowly to happen during this cooling. Later it was found that 1 - 2% Cr could replace Mn altho Cr or Mn alone would not yield a self-hardening steel. Mn also may replace W 1/2 as much only being needed to produce the same effect but this metal



has a tendency to make the steel fire crack on forging and such steels are not so reliable as the W. steels. The Taylor White process of tempering special steels is distinctive in that it gives a tool which will work at much higher temperatures than the carbon or self-hardening steels without softening. This property is obtained by cooling a special alloy of iron, carbon, tungsten or molybdenum and chromium from a heat near the setting point either slowly or rapidly to ordinary temperatures. The high first heat is the distinctive point of the treatment and does not turn the steel as it would a carbon steel but renders it hard both at ordinary temperatures and up to a red heat. Molybdenum is not so suitable as tungsten in these steels, making them liable to be more brittle but it may be used. A steel as low as 1% W and 1/2 % Cr may be treated by this process but the best tools contain about 18% tungsten and 55% Cr. with Carbon .6 - .7%, while ordinary carbon tool steels usually contain about 1% C .2% Mn and .2% Si. The % of tungsten in all the steels tested was sufficient with proper % Cr. to render them self hardening and suitable to the Taylor White process. The high % Mn in the International steel would tend to make it difficult to forge and in fact it did develop some fireworks. The Cr in the Vulcan is too low to make as good self hardening tool or one with lower carbon .6 - .7% all of these steels would probably be less brittle any very nearly as hard. The very high % Cr. and W in the Bethlehem steel probably renders it a little harder and more brittle than it should be.



## IV (A) Method of Manufacture.

### (b) (1) Crucible Steel.

Cast or crucible steel was first produced upon a working scale and introduced into Sheffield by Huntsman in 1740, when he succeeded in effecting the entire fusion of the metal placed in crucibles standing upon the bars of an air furnace which was heated by a coke fire surrounding the crucible and finally he cast or poured the molten steel into cast iron moulds for the production of homogeneous ingots. The practice as then introduced is still pursued practically without modification in Sheffield and other crucible steel producing works on a large scale, for the manufacture of special steels.

Cast, crucible, or homogeneous steel, as the same product is variously called, is hence largely produced by the melting of blister steel in crucibles or pots; whilst bar iron, carbon, manganese ores, or Spiegeleisen are one or more of them frequently added to the charge of blister steel, according to the temper and quality of metal to be obtained in the cast ingot. But cast crucible steel is also very largely produced by the fusion in crucibles of bar iron or puddled steel along with carbon black oxide of manganese, or spiegeleisen in small proportions.

The steel melting house or "furnace" as the part of the works devoted to the melting and casting of steel is called, is somewhat variously arranged according to the class and weight of work intended to be carried on therein; but as arranged for casting the usual run of small ingots required for the very extensive light trade of Sheffield, the furnace or melting house consists of various numbers of "melting holes," or "fires," arranged along on both sides of the melting house. The construction of the melting holes is the same, except as to size, for both the light and heavy trades, but the general arrangements of the melting department are somewhat modified. In the middle of the floor of the melting house are the "teeming holes" or small pits of about 3 feet in length

THE JOURNAL OF THE

ROYAL ANTHROPOLOGICAL INSTITUTE

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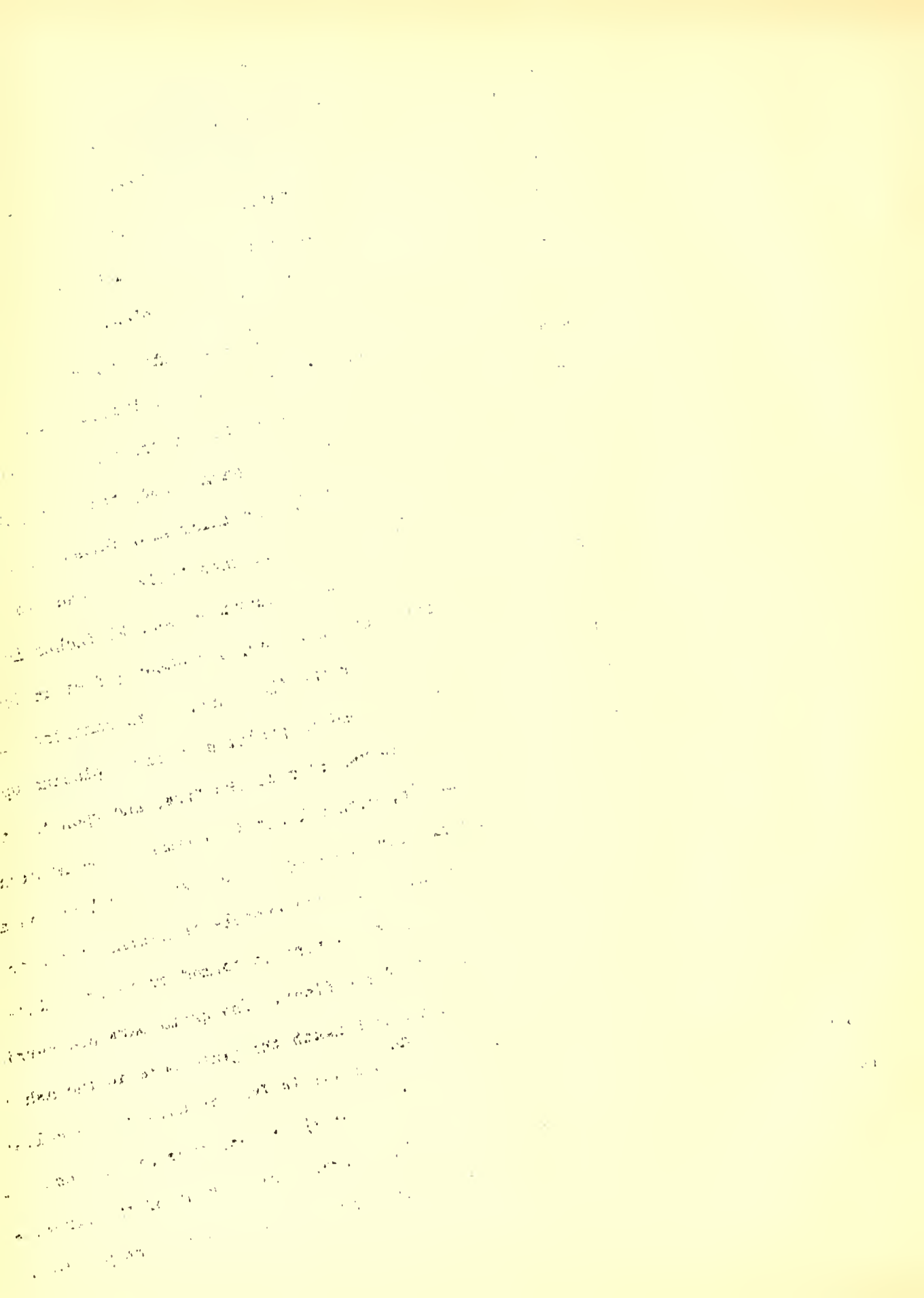
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and 2 feet in width, with a depth varying with the ~~length~~ length of the ingots to be cast. The teeming holes are covered over with iron plates placed level with the general floor except during the period of casting or teeming, or the preparation for the same. The bottom of the pits are prepared with a layer of small coke, upon which the several moulds stand for the reception of the metal from the crucibles.

The melting holes or fires form a series of rectangular chambers arranged along the sides of the building and which measure about three feet from the center of one hole to the center of the next, a single brick wall separating the holes from each other; but each hole is lined with a refractory lining of some 6 inches in thickness, formed of fire brick tiles or of ganister, so that the melting hole when finished ready for the reception of the crucibles, is an oval chamber measuring about 26 inches in its major diameter by 19 inches in its minor diameter, and about 5 feet in depth from the level of the floor to the top of the fire bars. When ganister, as is usual, forms the lining material, it is rammed in position by first placing upon the grate bars a wooden model of the internal form of the fire, and upon the top of which the workman stands and rams in, with a light iron rammer, the moistened ganister placed around the model, thus leaving, on the withdrawal of the model, a cavity of the dimensions above mentioned and capable of holding two pots or crucibles. The top around the mouth of the fire is formed by an iron plate placed but very little above the level of the floor. The grate bars are carried upon bearers, built in the masonry, while beneath the grate bars is the ash pit, the bars and the ash pit being readily accessible from an underground cellar or vault, which runs parallel with and in front of the fires, thus giving access to the bottoms of the running pots and the like during the working of the fires, since by withdrawing a fire bar or two, enough fuel falls into the ash pit to enable the workman to examine



and, maybe, to stop the hole in the running pot, etc. The cover of the fire is formed by a square fire brick, tile, quarry or slab, about 3 inches in thickness, held in a wrought<sup>iron</sup> frame provided with a projecting bar or handle for moving the cover from over the hole. Each fire is provided with its own flue in the form of a small rectangular passage of considerably less sectional area than the furnace itself; this flue leads into a flat vertical chimney or stack of about 40 ft. in height which is continued downwards below the flue to the ash pit into which it opens and by the insertion of a brick into this opening and also into the flue, the draft of each fire can be regulated so as to either urge or to keep back the fires as may be necessary when making large ingots, in order that all the metal may be melted and in proper condition for teeming at the same time. Five or six of the vertical or chimney flues are carried up together, forming one block or stack for as many holes as there are flues, the adjoining batch of holes to the same number having their flues carried up together in the same manner. Each fire<sup>or</sup> hole as thus described holds two pots or crucibles, each supported upon its own stool or stand of about 4 inches in thickness, to which height the crucible is raised above the bars.

Around the sides of the melting house are fixed shelves upon which the fresh or green crucibles are placed for drying before use; while outside the walls of the melting house it is usual to place the sheds in which the clay for the manufacture of the crucibles or pots is stored for drying and tempering by the heat of the walls of the melting house.

The crucibles employed in steel melting are usually from 16 - 18 inches high and 6 or 7 inches in diameter at the mouth but special crucibles of larger sizes are now frequently used. These pots are made of mixtures of fire clays from the coal measures, with pot sheds, coke dust, graphite, etc., and are covered by lids during the fusion of the charge of metal, the lids being also made from fire clays,

[illegible]

1. The first of these is the fact that the  
2. The second is the fact that the  
3. The third is the fact that the

The first of the two main parts of the book is devoted to the study of the structure of the group  $G$  of automorphisms of the algebra  $A$ . The second part is devoted to the study of the structure of the algebra  $A$  itself.

1. 1980年12月，在“六四”事件后，邓小平在中央政治局扩大会议上，对“六四”事件进行了总结，指出“六四”事件是“反革命暴乱”，并决定对“六四”事件进行“彻底清查”。

These findings are particularly important in view of the fact that the majority of the respondents are from the private sector, and the results suggest that the private sector is more likely to be involved in the development of the country's infrastructure.

1. The first group of people who are in the process of being  
2. The second group of people who are in the process of being  
3. The third group of people who are in the process of being  
4. The fourth group of people who are in the process of being  
5. The fifth group of people who are in the process of being

1. The first point is that the Commission has not received any information from the Government of the United Kingdom regarding the proposed changes to the law.

... ..

but of an inferior class to those employed for the crucibles. The crucibles are each annealed before used; they are usually placed in the annealing ovens in the afternoon or evening and left there until the following morning, when they are at a black red heat and are removed by tongs for conveyance to the melting holes into which each is inserted and placed upon its own stand in the fire.

The pots having been thus placed in the melting holes, into which a small quantity of live coals has been previously introduced, the fires are now filled up with coke to the level of the top of the crucibles and the whole is allowed to burn up slowly, so that in from twenty to thirty minutes, the pots are at a red heat and charging of the metal into them comes.

The charge of blister steel, which has been previously assorted and broken up into small pieces, and weighed up into the crucible charges of from 40 to 60 lbs. each, is now introduced into the crucibles through a wrought iron funnel shaped charger, placed by one man over the mouth, whilst another empties the charge of metal from the pans into the mouth of the charger, a little black oxid. of manganese being also sometimes added along with the charge. The cover of each crucible is now replaced and the fires are made up with hard coke to slightly above the level of the flue when the cover is placed over the melting hole, and in from 45 to 55 minutes this first fire will have burnt off. The workman introduces his bar and potters down the fuel hanging about the bottom and sides of the pots, so that in the next firing the coke gets down to the bottom of the pots, for otherwise, whilst the top of the pot would be red hot, the lower end would be comparatively cold, and the metal probably set in the crucible owing to the fire drawing in cold air at the bars, which would not meet with combustible coke for some distance up the pots and hence the surface of the fire and top of the crucible would be at the highest temperature. Although the bottom might be cold. When the second fire has burnt off, the charges will have begun

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the ninth part

the tenth part

the eleventh part

the twelfth part

the thirteenth part

the fourteenth part

the fifteenth part

the sixteenth part

the seventeenth part

the eighteenth part

the nineteenth part

the twentieth part

the twenty-first part

the twenty-second part

to melt, and the lids of the crucible are then turned off, when the melter goes round with an iron bar and introduces it into each pot, by which he can feel whether the metal is all fused, or whether any lumps of unmelted metal still remains, and he gives instructions accordingly as to the amount of fuel to be added to each hole in this third and last firing, so that the whole number of crucibles may be ready at the same time. When the third fire has burnt off, the charges in the several pots ought to be in a complete state of fusion and ready for teeming. The melting thus occupies from 4 to 5 hours according to the temper etc., of the steel.

The crucibles with its contents of fluid metal is withdrawn from the fire with tongs and landed on the floor by the "puller out." Before teeming the metal in the crucible is first skimmed or cleared of the slag floating on its surface, whereupon the clean surface of the metal presents itself and the teemer judges of the best heat at which to cast the metal, allowing it to stand in the crucible for a minute or two, if he judges it to be too hot.

After teeming is completed, the pots, if in good condition, are again received in the barrows and returned to the pullers out at the fires, who, after detaching adhering slag and clinker from the bottom of the pots, replaces them in the fires for the reception of a second charge.

#### IV. (A) b-2. THE HEROULT FURNACE AND PROCESSES.

Mrs. Paul Heroult, the French inventor of the process for extracting aluminium from its oxides by electrolysis, was born in Thury Harcourt, Normandy, in 1863 and was educated locally as a mining engineer. He was only 23 years of age when he patented his process for aluminium extraction and in 1887 he was acting as technical manager of the first erected aluminium works in Europe at Nevers. As stated above H. Heroult turned his attention in 1899 to the production of ferro chrome ferro silicon and ferro tungsten in a modified form of the electric

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furnace used for aluminium production and it was the success of these attempts that suggested to him the use of electric heating in the iron and steel industry. Two distinct furnaces and two distinct methods of work have resulted from these experiments. The one a tilting electric crucible furnace for steel manufacture, the other a modified form of the blast furnace, with electric heating for pig iron manufacture. These will now be described in the order named.

(1) The Heroult electrically heated crucible furnace.

This furnace consists of a low shallow iron tank thickly lined with a refractory material which will stand the high temperature attained within the furnace without undue softening or corrosion by the slag. This lining consists of dolomite brick, with magnesite brick around the openings. The hearth is formed of crushed dolomite, rammed on top of the dolomite brick lining of the bottom of the furnace. The furnace is mounted on two curved and coggled bars, which permit of its being tipped sideways and held at any desired angle for discharging purposes. At the opposite side from the discharge lip there is an inlet for the air blast, and also an insulated supporting frame work for carrying the two massive solid carbons, 1.7 metres in length, and 360 mm. square, which convey the electric current. These can be moved either in a vertical or horizontal direction by use of gearing. Openings are provided in the top of the furnace cover for charging, for inserting the two electrodes, and also for the escape of the gases produced on heating the charge. This latter can be effected either by arc or resistance heating. In the former case, the electrodes are allowed to touch the surface of the slag or metal, and are then raised upwards to the limit of distance which the arc will strike, with the current and the voltage at command. Two arcs will be formed under these conditions one as the current enters the charge of slag or metal, and one

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as it leaves the same while in between these two points the current will traverse the slag and produce resistance heating.

When resistance heating only is desired the two electrodes are lowered until they dip beneath the surface of the charge and the current in this case passes from one to the other entirely by the materials forming the same.

The method of producing steel in this furnace is as follows:- A charge of steel scrap, pig iron, iron ore and lime - in the requisite proportions and quantities - is placed in the furnace, and this is raised to the melting point by combined arc and resistance heating. The slag formed by the lime and silicates of the ore now rise and float on the surface of the molten metal and the further heating of the charge occurs by allowing the electrodes to dip just beneath the slag, but not into the metal beneath it. An air blast is now allowed to enter the furnace at some suitable point, and under these conditions the impurities of the iron and steel scrap become oxidized and enter the slag. By pouring off this slag, therefore, and by renewing the materials which form it once or twice, a very pure product can be obtained. The process is in reality a washing out process, in which the slag acts as solvent. The fact that all the heating with this type of furnace occurs without any actual contact between the carbon electrodes and the metal also conduces to purity of the products, since no silicon or carbon can enter into the iron or steel from the electrodes. When the iron in the crucible has been raised to the requisite degree of purity by this washing out process, a calculated amount of an iron alloy high in carbon is added, and the resultant steel - of known carbon contents - is tipped into the casting ladle.

A similar method is followed when making ferro alloys, the requisite weight of alloy, high in the percentage of the metal or element desired, being added to the contents of the crucible just before tipping. The crucible furnace



usually employed for this process produce three tons of finished steel per charge and two charges per day of 20 hours, the current required being 4000 amperes at 120 volts pressure, or 480 K.W. The following test shows the average composition of this steel:-

|           |      |             |       |
|-----------|------|-------------|-------|
| Iron over | 99%  | Silicon     | .03%  |
| Carbon    | .6%  | Phosphorous | .005% |
| Manganese | .15% | Sulphur     | .007% |

One of the test runs made by the Canadian Commission of experts at LaPraz with the Heroult steel furnace gave the following results:-

The charge was made of 3,307 $\frac{1}{2}$  of iron scrap, 330 $\frac{1}{2}$  of iron ore, and 246 $\frac{1}{2}$  of lime, being purposely made small to reduce the time requisite for finishing the charge. When the charge had arrived at a tranquil molten state the slag was poured off and every care was taken to remove all of this from the metal left in the crucible. A new slag was now formed by adding the following materials, lime 55 $\frac{1}{2}$ , sand 15 1/2 $\frac{1}{2}$  and fluor spar 15 1/2 $\frac{1}{2}$ . When this slag had been melted it was likewise poured off and a new charge of slag forming material similar in weight and constitution was placed in the furnace. This formed the finished slag, and after its removal 1 1/2 $\frac{1}{2}$  of ferro manganese was added to the molten mass and the crucible was tipped for discharge. The total time required for furnishing the charge was 4 1/2 hours and 2,829 $\frac{1}{2}$  of steel of the following chemical constitution were obtained:-

|            |       |           |         |
|------------|-------|-----------|---------|
| Carbon     | .079% | Manganese | .230%   |
| Silicon    | .054% | Arsenic   | .095%   |
| Sulphur    | .022% | Copper    | trace % |
| Phosphorus | .009% |           |         |

The physical properties of this steel were good. The electrical energy required for its production was 1,410 K.W. hours equal to .153 E.H.P. year/ton of finished steel.

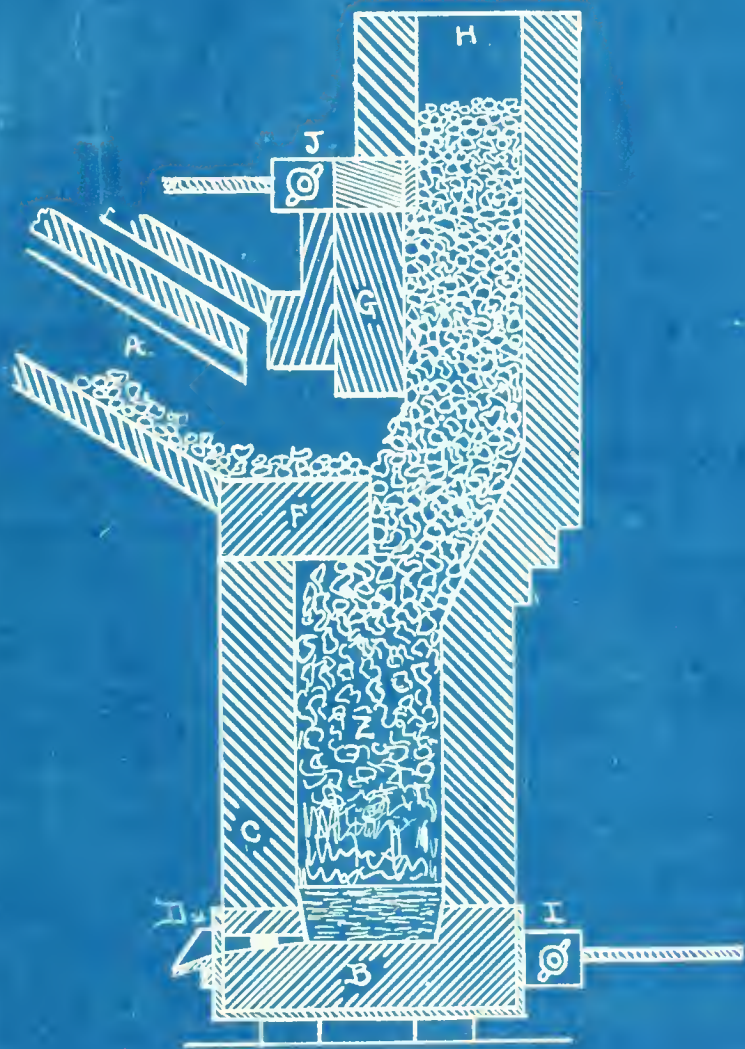
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At LaPraz eight grades of steel are made varying from tool steel of exceptional hardness, selling at £ 72 12 s per ton of 2000 # to tough mild steel, selling at £ 24 12 s. per ton. The cost of a 2500 kg. tipping furnace with all the accessories is given by Heroult as £ 2000 while another £ 1000 would be required for the electrode making plant. The electrodes are made from retort coke using tar as a binder .

## (2) The Heroult Smelting Furnace and Process.

The original form of this furnace is shown in sectional elevation in Fig. 3. The principle of the furnace is the continuous supply of the half fused ore and fluxing materials to a column of coke, maintained at a red heat by means of an electric current and resistance heating. A, in the figure, is the channel by which the ore and fluxing materials are supplied to the vertical reducing zone of the furnace, while H is the shaft by which the coke is charged. The gases passing away from the hot zone pass up A and thus heat the ore and fluxes before these arrive at the vertical shaft. G, F and B are solid carbon blocks which function as electrodes, the current terminals being placed I and J. The electric current passing from B to G through the coke maintains this at a red heat, and as the pasty mass of ore and lime passes between the carbon blocks F and G it is likewise heated by the current and rendered more fluid. The liquid charge of ore and lime in its latter descent through the hottest zone of the furnace (Z) spreads out and during its passage through the hot coke the iron oxide is reduced to metallic iron which collects in the hearth and is



run off by tapping both

run off by the tapping hole D.

This experimental furnace has been some what simplified in the light of more extended experience and the smelting furnace used in the trial runs for the Canadian Commissioners at LaPraz, consisted only of an iron box of square cross-section, lined with refractory and open at the top. The bottom of the casing was provided with a carbon plate, which acted as one electrode of the circuit, the other being a movable block of carbon of square cross-section, 3 ft. in length and placed vertically in the open top of the furnace. The distance between the electrodes was varied by hand regulation. The charge consisting of finely divided ore and coke, was placed in the square between the two electrodes and also around the upper electrode and fresh ore was added as that in the lower part of the furnace was reduced. The following are the details of the runs made with this furnace:-

3,280 k.w. hours, equal to 0.50 E.H.P. year. The total output of pig iron was 2130 $\frac{1}{2}$  and the power used was, therefore, 0.47 E.H.P. year per ton (2000 of pig iron. At £ 2 per electrical horse power year, the cost of the electrical energy required for the smelting operation was therefore 18 s 10d per ton of pig iron produced.

Let us now look at the yields and costs of the Heroult furnace.

Yield:- (a) (Steel from Pig Iron and scrap charged cold into crucible furnace with C. elect.)

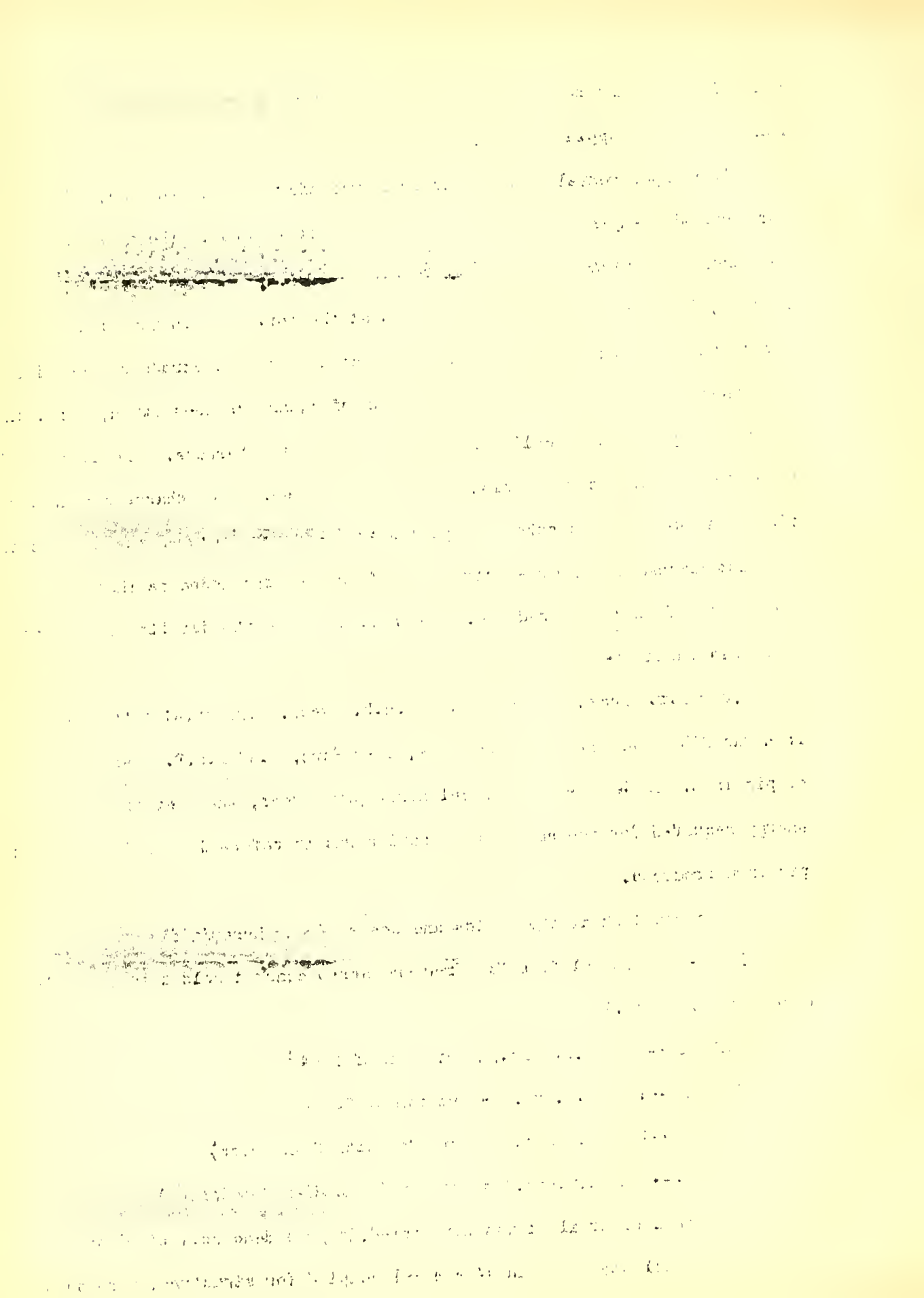
Trial #1 -- 882 k.w. hrs./metric ton of 2204 $\frac{1}{2}$

" #2 --1000 k.w.hrs./ short ton of 2000 $\frac{1}{2}$

" #3 --1000 k.w.hrs./ short (Canadian Commission)

" #4--- 653 k.w.hrs./ short ton ( Canadian Commission)

Quality of steel of trial #1 was not stated, in #2 a dead soft steel was produced in #3 a hard tool steel and in #4 a steel adapted for structural purposes.



and

(b) Steel Produced from scrap melted over oxidized in an open heart. furnace.

Trial #1 360 k.w.hrs./metric ton of 2204 #. This trial was made at the Remshied works in Germany and the quality of the steel was not stated.

(c) Pig Iron Production.

Trial #1 - 3,080 k.w.hrs./short ton

" #2 - 2,360 k.w.hrs./short ton

" #3 - 2,342 k.w.hrs./short ton

No. 1 gave a close grained grey pig

No. 2 gave a gray iron high in C & Si and No. 3 trial a similar iron with 3 - 4% Ni.

Taking the mean of the above values for each product we have the following figures for the Heroult process and furnace:-

(1) Steel from cold pig and scrap - 334 k.w.hrs./2000 #

(2) Steel from molten open hearth steel 329 k.w./2000 #

(3) Grey pig iron from ore 2,693 k.w.hrs./ 2000 #

(4) Ferro nickel pig from ore 2,342 k.w.hrs./2000 #

The costs of the process can be averaged up in a few figures as follows:-

(a) Steel from scrap. £ 2 15 s/ton of 2000 # exclusive of cost of scrap  
(Electric power at £2/E.H.P. year.

(b) Pig iron from ore:- £ 2/ton (ore at 5 s/ton)

The subject just discussed is just one of the many processes now in operation and is considered the best. The subject is a very wide one and many books have been written upon it. Mention might be made of the other important electric furnaces. They are as follows:-

The Keller Furnace

The Kjellin Furnace

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The Stassano Furnace

The Conley Furnace

The Calbraith Furnace

The Gin Furnace

The Girod Furnace

The Harmet Furnace

The Hiorth Furnace and

The Ruthenberg Furnace

Of all these the Heroult is the best known and used the most.

#### IV (B) Physical.

The physical properties of steel constitute a fairly accurate guide to its cutting speed and these properties are best indicated by the tensile strength and percentage of stretch and contraction of area obtained from standard tensile test bars cut from such a position in the body of the forging as to represent its average quality and then broken in a testing machine.

As the above tests depends greatly on the hardening and tempering of the steel, these two important factors might be taken up here.

Hardening:- Carbon Steels and ordinary tool steels that are made up into tools or implements are entirely too soft as they come from the forges for almost all cutting purposes. In order to prepare them for cutting, they must be hardened, and this is done by heating them to temperatures in accordance with their carbon contents, varying between a dark and a bright cherry red, say, from 1350 degrees Fahr. (735 degrees cent.) up to 1550 degrees Fahr. (845 degrees Cent.) and then by plunging them quickly into water or other suitable bath, cooling very rapidly to a temperature not exceeding 392 degrees Fahr. (200 degrees Cent.), or preferably to the normal temperature of the air. This operation is called hardening.



Tempering:- When cooled suddenly in this way, implements and tools made from carbon tool steel are too brittle for most cutting purposes. This quality of brittleness is removed or modified by reheating to temperature ranging between 392 degrees Fahr. (200 degrees Cent.) and 600 degrees Fahr. (315 degrees Cent.) The higher the tool is reheated within those ranges of temperatures, the softer it becomes and this reheating for the purpose of partially softening and at the same time toughening the tool is the operation known as "tempering" the tool." In many cases it is not practical to use a pyrometer and the question will immediately arise - How can one determine the temperature of the steel. The following table simplifies the question:-

#### Color Names for High Temperatures.

|                                 |            |
|---------------------------------|------------|
| Dark blood red, black red       | 990° Fahr. |
| Dark red, blood red, low red    | 1050° "    |
| Dark cherry red                 | 1175° "    |
| Medium cherry red               | 1250° "    |
| Cherry, full red                | 1375° "    |
| Bright cherry red, scaling heat | 1550° "    |
| Salmon, free scaling heat       | 1650° "    |
| Light salmon                    | 1725° "    |
| Yellow                          | 1825° "    |
| Light yellow                    | 1975° "    |
| White                           | 2200° "    |

#### IV C. Discussion and Conclusion - Mechanical.

The data obtained in shop test for cast iron are tabulated not only in actual life as obtained on the lathe but also are figured to life under standard conditions according to Taylor's formulae as noted before. Taylor's formulae however were obtained from runs of longer duration (20 minutes or more) and do not seem to hold for our runs. The reason probably is this:- The prime cause for failure of a tool is the softening of the cutting edge due to heating by friction with the work. When the tool is running at such a speed as will give 20 min. life or more the rate of input of work into the tool point is so slow that the tool does not at first become heated up but only after the cutting edge has gradually be-



come blunted so that the pressure on tool point has increased does the heat input greatly exceed the loss by radiation from tool. With the speeds which we used however the power input even with the tool sharp sufficed to heat up until the edge began to soften when it immediately gave so that our test was really a test more of what temperature the cutting edge would stand than of the hardness of the cutting edge and the formulae are not accurate statements of the conditions for such a test. The great difference between the last five and first five values in the last column which if the formulae held should be approximately equal for each tool show that they do not. The probability is that the life is proportional to the area of cut and cutting speed. With this understanding the ranking for cut on cast iron, primarily a temperature test is taking both cuts into consideration:-

Poldi, International, Heller, Bethlehem, Vulcan with an aggregate life of 24.5, 23.9, 20.5, 10.5, and 9.2 minutes respectively.

When turning the steel specimen since we had a very small piece of metal to work on it was necessary to cut at extremely high speed and the results are probably not so reliable as those for cast iron. The test, being so short is even more than that on C.I. a determination of the strength of the tool at high temperatures. The ranking in this test was as follows:-

Poldi, Heller, Bethlehem, International, Vulcan.

The higher rate of cutting possible with the steel is due to the fact that the metal is more ductile than C.I. and so the chip flows out over the surface of the tool distributing its heat and pressure to the whole tool point instead of to the cutting edge alone as does the more brittle cast iron.

To regard these conclusions as a measure of their value would be an injustice to the steels for several reasons. In the first place tools are not run at such high cutting speeds as those we used, secondly the heat treatment such as for these steels to get best efficiency should be the Taylor White which gives a

The first of these is the fact that the  
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 the necessary funds to carry out its  
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 internal affairs of the country.  
 The second is the fact that the  
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 The tenth is the fact that the  
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 internal affairs of the country.

of tool better capable standing high temperatures. The quality of the metal cut especially in the case of cast iron is liable to great variation in the different parts of the piece and the data itself is rather uncertain as was shown by the fact that a number of the tools broke in the first few seconds striking the work.

#### IV (D) (a) History - Crucible Method.

It would doubtless have been felt by many but a few years ago that there was little left to be said on the subject of crucible tool steel and that something akin to finality had been arrived at in its manufacture and general treatment. Probably such feeling was justifiable when it is remembered that the making of steel in crucibles is by far the oldest method known, dating back from time immemorial, it being indeed impossible to accurately trace its origin and earliest development, but it seems certain that carbon steel was made and used thousands of years ago for cutting tools. Proof of this may be seen by the marvellous carvings and workings on the intensely hard stone work of the ancient, for it would be difficult to conceive by what means, other than with steel tools, such work could have been executed and it is wonderful to contemplate that steel cutting tools should have been used so long ago, whilst the principle of manufacturing them that is, by fusion of iron and charcoal in crucibles - was then in a measure on the same lines as the work is done at the present time. Archaeologists have discovered that the Chinese made steel in crucibles long before the Christian era. "Wootz" steel fabricated in India centuries ago was crucible steel as was also the celebrated Damascus steel, produced at the forges of Toledo. It is recorded that this Damascus steel contained certain percentages of tungsten, nickel, manganese, etc., some of the very elements, in fact, contained in the present modern high speed steel, so that a latent high speed steel may be said to have existed centuries ago, and all that was necessary to bring out its



inherent powers would have been the heating of it in a paradoxical manner, so to speak; that is, to such a high degree of temperature as was long thought would impair or destroy the nature of such steel. When, therefore, we look back on the period for which crucible steel has been known in the world's history, some may not unnaturally think that there has been time enough to have fully fathomed its mysteries leaving little more to be said on the subject. It is then all the more remarkable that a discovery, made but a few years back, and which has since revolutionized the treatment of crucible tool steel, should have remained so long a hidden secret.

A very important advance was made thirty or forty years ago, when "Mushet," or self hardening steel, was introduced. This was the valuable invention of Robert Mushet, who, after a long series of experiments, made whilst he was manager of the Titanic Steel Co., succeeded in producing a tungsten steel, and its introduction was a great advancement on the cutting powers of ordinary crucible steel, and for many years "Mushet" steel held a foremost place amongst tool steels.

It is now to America, however, that all honor must be given for the next great step in having "set the pace" and led the way in the present remarkable advancement in special steels and the greatest credit is due to Messrs. Taylor and White, who at the Bethlehem Steel Works of America, initiated high speed cutting, and at the exhibit of their firm in Paris some years back, what were then considered to be astonishing results in speeds of cutting steel were publically demonstrated. Since then, still greater developments have been made by the above firm in special steels and with increased experience in its manufacture, treatment and application, results in cutting powers far beyond expectation have been attained.

Let us now look along another line of the history of the production of special steel

1. The first part of the report deals with the general situation of the country and the progress of the work during the year. It is divided into two main sections: the first section deals with the general situation and the second section deals with the progress of the work.

2. The second part of the report deals with the results of the work during the year. It is divided into two main sections: the first section deals with the results of the work in the field and the second section deals with the results of the work in the laboratory.

3. The third part of the report deals with the conclusions of the work during the year. It is divided into two main sections: the first section deals with the conclusions of the work in the field and the second section deals with the conclusions of the work in the laboratory.

4. The fourth part of the report deals with the recommendations of the work during the year. It is divided into two main sections: the first section deals with the recommendations of the work in the field and the second section deals with the recommendations of the work in the laboratory.

5. The fifth part of the report deals with the summary of the work during the year. It is divided into two main sections: the first section deals with the summary of the work in the field and the second section deals with the summary of the work in the laboratory.

#### IV. (D) (b) History.

In the year 1879 the late Sir William Siemens of London, patented a crucible form of electric furnace. In this furnace he was able with comparative ease to melt 10 kg. of iron or steel by the aid of the electric current in one hour.

Basing his estimate of cost upon the results obtained by experiments with this furnace, Sir William Siemens claimed that the electric furnace method of melting steel might be regarded as equal in heating efficiency to a regeneration gas furnace, since in each case the ton of steel required the equivalent of one ton of coal or coke.

But the electric furnace had other advantages in its favor not shared by furnaces using solid or gaseous fuel, chief of these being that the atmosphere of the furnace was uncontaminated with the products of combustion, that practically any degree of heat could be obtained in the charge of steel within the furnace, and that this heat could be easily controlled by regulation of the electric current. On these grounds the designer of this earliest form of electric crucible furnace prophesied that electric heating would become of considerable importance in the iron and steel industry of the future.

Twenty years elapsed before any progress could be reported in the direction indicated by the late Sir William Siemens. But the mean time much important work was carried out by the brothers Cowles, Hall, Wilson and Acheson in America, by Herould and Girod in France, by Borchers and Kiliano in Germany and by de Lavel in Sweden, bearing upon the practical application of electric heating in the production of aluminium, calcium carbide, carbonandum, graphite, ferro-alloys and zinc. Moissan's researches, although confined to the laboratory must also be mentioned in this connection, for this famous French chemist's work with the electric furnace has become of classical value and importance.

1. The first part of the paper is devoted to the study of the properties of the function  $f(x)$  defined by the equation  $f(x) = \sum_{n=0}^{\infty} \frac{f_n(x)}{n!}$ , where  $f_n(x)$  are the functions defined by the recurrence relation  $f_n(x) = \frac{1}{n!} \frac{d^n}{dx^n} f(x)$ . It is shown that the function  $f(x)$  is analytic in the domain  $|x| < 1$  and that it satisfies the differential equation  $f'(x) = f(x)$ .

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In these laboratory and works trials of the electric furnace much valuable information relating to the use of electricity for heating purposes was gained. The best methods of controlling the large currents used, and of arranging the ~~large electrodes~~ electrodes so as to minimize their loss and destruction during the heating of the charge in the furnace, were also worked out.

In 1899 Heroult - who had patented and brought into successful operation in Europe the process of aluminium extraction associated with his name about the same time that Hall patented and introduced a similar process in America - turned his attention to the utilization of the electric furnace for the production of special alloys of iron and steel. A large number of trials were made in the works at Troges and LaPraz, in France, with various forms and designs of furnace.

Success attended this early experimental work of Heroult and from the production of ferro-alloys in the electric furnace to the manufacture of high class steels was a natural development of his process. Attempts to smelt iron ore directly by aid of electric heat were made about this date, but were not so successful, and Heroult from 1901 - 1905 confined himself chiefly at La Praz to the production of special steels, using scrap and pig iron as the starting point in the process. In this same period Stassan in Italy, Keller, Heroult and Gin in France and Kjellin in Sweden were working along the same line, and each of these electro metallurgists had attained some degree of success in the production of special steels by the new method of heating. In America, Rutherbergh, Conley, Rossi and Wilson were also experimenting with the applications of the electric furnace in the iron and steel industry. Early in 1904 these methods had become of sufficient importance for the Canadian Government to think it worth while to appoint a commission of experts to proceed to Europe to examine their working and the report of this commission published at the end of 1904 attracted much attention from metallurgists in all countries.

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The Heroult Steel Furnace is being operated at La Prez and Froges in France, at Kortfors in Norway, at Lenscheid in Germany and at Syracuse in the United States, in each case the plant being designed for the industrial production of steel from pig iron and scrap, while at Sault Sainte Marie, in Canada, experiments have recently been conducted with the Heroult furnace for the smelting of iron ore. These experimental trials were carried out at the expense of the Canadian Government under the personal charge of M. Heroult himself and the results obtained are stated to have been of considerable promise and value as regards the building up of a new center of the iron and steel industries at Sault Saint Marie in Canada.

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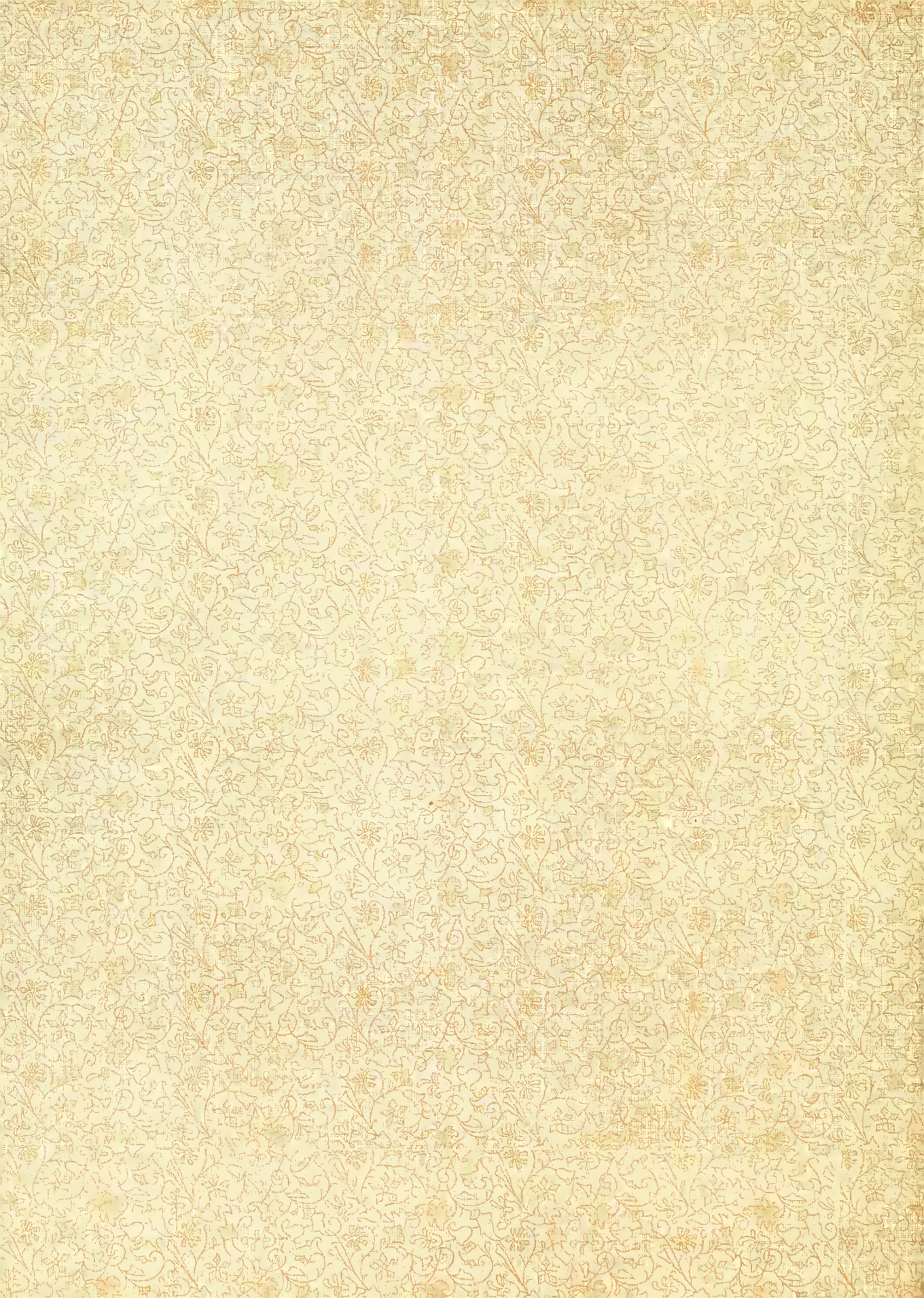
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